of the suspected products of the violent reaction, it appears that both bonds are eventually broken. Thus we may conclude that chlorinated sulfides can be oxidized by dinitrogen tetroxide to the corresponding sulfoxides if measures are taken to prevent the formation of dinitrogen trioxide by scavenging the reaction mixture with oxygen. The yields of the sulfoxides will, however, be somewhat less than quantitative.

Experimental

Materials. Bis(chloromethyl) sulfide was prepared by the reaction of trithiane and thionyl chloride (Truce, Birum, and McBee, 1952). Matheson Co. dinitrogen tetroxide was purified by passing the gas through a tube filled with a mixture of phosphorus (V) oxide and sand and then condensing the dry dinitrogen tetroxide in a dry ice trap. If the solid dinitrogen tetroxide was snow-white, it was stored in a refrigerator until needed. However, if the solid showed any traces of green or blue, indicating the presence of dinitrogen trioxide, further purification was effected by bubbling dry oxygen through liquid dinitrogen tetroxide at 0°. The dinitrogen trioxide which was used in some of the experiments was prepared by dissolving nitric oxide in liquid dinitrogen tetroxide at 0°. In this way, a solution of dinitrogen trioxide in dinitrogen tetroxide was obtained. The nitric oxide was generated by the action of 5 *M* HNO_3 on copper pellets. The bis(chloromethyl) sulfoxide and bis(chloromethyl) sulfone were prepared by the oxidation of bis(chloromethyl) sulfide using standard procedures (Mann and Pope, 1923; Truce, Birum, and McBee, 1952).

Reactions. The reactions reported in Table 1 were carried out in an all-glass system equipped with a sealed stirrer and protected from the atmosphere with phosphorus (V) oxide drying tubes. In all experiments, the nitrogen oxide reactants were in great excess. Mole ratios of nitrogen oxide to sulfide were typically 10:1 to 20:1. Overall quantities were, however, small, usually less than 30 grams.

Literature Cited

Addison, C. C., and J. C. Sheldon. 1956. Oxidation of dialkyl sulphides and trisubstituted phosphines by dinitrogen tetroxide. Molecular addition compounds with dialkyl sulphoxides. Jour. Chem. Soc. (London), vol. 533, pp. 2705-2708.

Longhi, R. 1963. I. Reactions of nitrogen (II) oxide. II. Transition metal complexes of Lewis bases. Ph.D. Dissertation, University of Illinois, Order no. 63-5118, University Microfilms, Ann Arbor, Mich.

Mann, F. G., and W. J. Pope. 1923. The a-a'-dichlorodialkyl sulphides. Jour. Chem. Soc. (London), vol. 74, pp. 1172-1178.

Truce, W. E., G. H. Birum, and E. T. McBee. 1952. Chlorination of dimethyl sulfide and some of its derivatives with sulfuryl chloride and thionyl chloride. Jour. Amer. Chem. Soc., vol. 74, pp. 3594-3599.

Whitaker, R. D., and H. H. Sisler. 1960. Reactions of dinitrogen tetroxide with alicyclic sulfides. Jour. Org. Chem., vol. 25, pp. 1038-1039.

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THE PHYLLOSOMA LARVAE OF *PARRIBACUS*

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During routine sampling of the plankton of the Florida and Yucatan Straits for the phyllosoma larvae of the Florida spiny lobster, *Panulirus argus* (Latreille), 1579 phyllosomes of an uncertain species were captured. These larvae are similar to the phyllosoma larvae that Gurney (1936) called "*Thenus*?" and are the same, with the exception of Phyllosome D, as the larvae reported in my paper on four giant scyllarid phyllosomes captured in the Florida Straits (Sims, 1964).

Evidence reported in this paper will show: (1) These larvae and the larvae described by Gurney as *Thenus*? cannot belong to that genus; and (2) Gurney's suggestion that his phyllosomes might belong to the genus *Parribacus*, is correct.

The 1579 phyllosomes captured represent a size range from 1.3-41.2 mm and no doubt cover the entire development except for a few of the late stages.

The findings of this study are not final, and I do not wish to give the impression that the stages described here are the only stages in the larval development of this species. The phyllosomes described and illustrated in this report represent the average state of development in a given size range. I am aware of the probability that there are more stages than I discuss, but based on facts I will reveal, I feel I could do no more than guess if I described any more stages without the help of laboratory-reared larvae.

Methods and Materials

Standard tows were made at random with a conical California type plankton net with a diameter of one meter at the mouth and about 15 meters in length. The main body of the net was constructed of No. 30 grit nylon gauze with a finer section of No. 56 grit nylon gauze at the cod end. It was lowered into the water to a depth of 150 or 300 feet and was brought to the surface over an oblique tow which brought it from total depth to surface in 30 minutes. At the same time another net of the same type was towed just below the surface. Phyllosoma larvae were captured in both nets. The largest numbers were taken by the deep net during the day and by the surface net at night.

With the aid of a Bausch & Lomb Stereozoom microscope, all the phyllosomes in each sample were picked from the plankton. The various known and unknown species were then separated. The number of larvae for each species and the total length of each larvae were recorded. Table 1 gives the total number of phyllosomes taken, the size range, and mean and modal sizes for each trip.

TABLE 1

Size and occurrence of phyllosomes

Date	Stations (no.)	Larvae (no.)	Length (mm)	Mean (mm)	Mode (mm)
Aug. 1962	42	98	2.1-12.6	6.1	5.0, 5.3
Sep. 1962	42	5	3.3-16.0	10.8	none
Oct. 1962	38	37	5.6-18.0	11.3	8.0
Dec. 1962	56	14	14.0-41.2	24.4	14.0
Jan. 1963	25	3	14.0-26.2	21.1	none
April 1963	76	14	1.3-2.5	1.9	1.8, 2.0
June 1963	115	48	1.6-18.1	6.0	1.7
Aug. 1963	29	1360	1.7-14.8	7.0	7.2
		1579			

In addition 554 larvae, selected at random, were measured meristically and observed for the points listed on tables 2-4. All of the very small and very large phyllosomes were measured.

Drawings (Figs. 1-12) were made of average larvae in a one millimeter size range, 1.5 mm, 2.5 mm, and so on, in an effort to see possible stages. The result is 12 possible stages that represent a partial cross section of the many stages of development. Only by the rearing of laboratory hatched phyllosomes can one expect to complete with some accuracy the picture of complete larval development.

PHYLLOSOMA LARVAL STAGES

Data now available from Japan, on the rearing of several species of spiny lobster larvae (Nonaka, Ohshima, and Hirano, 1958; Saisho, 1960, 1962, 1964; Inoue and Nonaka, 1963) indicate that there are more stages in the phyllosoma larval development than have been suggested or reported in past work. Classical papers on the com-

plete larval development of certain species of spiny lobster indicate that the total number of stages is between 9 and 13. For example, Stephensen (1923) reported 9 stages in *Scyllarus arctus*. Bouvier (1914) reported 10 stages in *Palinurus vulgaris* (Latr.). Lewis (1951) reported 11 stages in *Panulirus argus* (Latr.). Johnson (1956) reported 11 stages in *Panulirus interruptus* (Randall). Prasad and Tampi (1959) reported 10 stages in *Panulirus pencillatus* (Olivier), and Gurney (1936) predicted 9 to 13 stages in the various species with which he worked. Gurney, however, did not have enough material to complete a series for any species.

TABLE 2

Characteristics of larval stages I-IV in *Parribacus*

Stage	I	II	III	IV
Specimens	29	32	60	69
Size (mm)	1.3-1.9	2.0-3.3	3.2-4.5	4.4-5.4
Antenna length (mm)	0.35-0.50	0.30-0.50	0.25-0.40	0.30-0.45
Antenna segments	2	2	2	2
Antennule length (mm)	0.60-0.90	0.70-1.0	0.80-1.3	1.1-1.8
Antennule segments	1	1	1	1
Eye & stalk length (mm)	0.60-0.80	1.0-1.6	1.4-2.2	2.0-2.7
Maxilla 2	bud, 4 setae	2 segments, 4 setae	*	*
Maxilliped 1	none	*	*	*
Maxilliped 2	no exopod	*	*	*
Maxilliped 3	no exopod	*	*	*
Coxal spines	present	*	*	*
Leg 1	complete	*	*	*
Leg 2	complete	*	*	*
Leg 3	no setae	*	complete	*
Leg 4	bud	*	long bud	complete
Leg 5	none	*	*	bud
Abdomen	unsegmented	*	*	*
Uropod	none	*	*	*
Telson	none	*	*	*

* Same as previous stage.

To my knowledge no one has been successful in raising the phyllosoma larvae through the complete number of stages. The best attempt is reported by Saisho (1962), who was able to raise the phyllosome of *Panulirus japonicus* (V. Siebold) through 11 stages of development. If we compare Saisho's stage XI with the stages of *Panulirus* (Lewis, 1951; Johnson, 1956; Prasad and Tampi, 1959), we find it compares closely with their stage V, less than half the total development, thereby indicating there must be more than 11 stages. In his abstract Saisho stated, "Although it has been claimed eleven or thirteen stages will occur before the meta-

TABLE 3

Characteristics of larval stages V-VIII in *Parribacus*

Stage	V	VI	VII	VIII
Specimens	67	235	37	18
Size (mm)	5.3-6.3	6.2-11.0	11.0-14.4	14.4-22.5
Antenna length (mm)	0.35-0.45	0.30-1.7	0.50-1.2	1.4-2.5
Antenna segments	2	2	3	3
Antennule length (mm)	1.2-1.9	1.5-2.3	2.0-2.5	2.5-3.5
Antennule segments	2	3	3	4
Eye & stalk length (mm)	2.4-3.0	2.8-4.5	4.4-6.2	6.2-8.6
Maxilla 2	*	*	base expanded	*
Maxilliped 1	*	*	*	*
Maxilliped 2	*	*	*	*
Maxilliped 3	*	*	*	*
Coxal spines	*	yes, no	no	*
Leg 1	*	*	*	*
Leg 2	*	*	*	*
Leg 3	*	*	*	*
Leg 4	*	*	*	*
Leg 5	*	*	*	*
Abdomen	*	*	segmented	pleopods
Uropod	forming	single	*	single double, unequal
Telson	*	*	formed	*

* Same as previous stage.

morphoses into the puerulus, judging from the difference in the morphology between the eleventh stage phyllosoma and the last stage larvae, the animal probably undergoes more frequent ecdyses during the phyllosoma stage." If one reads the work of Saisho, it becomes apparent that the morphological differences between the early stages are easily distinguished, while in the middle and late stages these differences become more subtle, and in some cases the only difference is in size. These size differences sometimes overlap and make it difficult and precarious for the person working solely with plankton collections to distinguish the possible stage of a given phyllosome. Lewis (personal communication) states, "It is only in the early stages of these larvae that individuals of each stage are morphologically similar. In the later stages there is great variation amongst individuals of the same stage."

The danger in assuming the number of a given stage and the total number of stages in the larval development of a species is shown by the work of Costlow and Bookhout (1960). In their work on the rearing of the larval stages of the grapsid crab *Sesarma cinereum* (Bosc), they found only four of the long-predicted 5 zoeal stages. They state, "The presence of four zoeal stages in *S. cinereum* further points out the danger in generalizing on the number of larval stages a particular species of decapod should have." Costlow (personal communication) feels that physical factors, such as diet, temperature, and probably salinity, act on some larvae in such a way as to interfere with what we usually consider the normal number of stages. Inoue and Nonaka (1963), using Brooks formula, predicted 14 stages in the larval development of *Panulirus japonicus*. Saisho's documented evidence of 10 ecdyses in *P. japonicus* to a larvae about half way through its total development indicates that these methods are inadequate to show the true number of larval stages.

Of the 12 stages described in this report, stage I, because the eyes are not stalked, is no doubt the first stage and should correspond with laboratory hatched specimens. Stage II would follow because it is the first stage in which the eyes are stalked. Beyond stage II, and until the last stage, I cannot be certain of the point ecdysis takes place. The presence of bilobed gills is thought to signify the last stage before the puerulus (Gurney, 1936). With this evidence I think I am safe in assuming that my stage XII is equal to the final stage.

TABLE 4

Characteristics of larval stages IX-XII in *Parribacus*

Stage	IX	X	XI	XII
Specimens	2	2	1	2
Size (mm)	22.5-27.0	27.0	33.4	36.0-41.2
Antenna length (mm)	2.5-3.0	4.0	4.8	6.0-7.2
Antenna segments	4	4	4	4
Antennule length (mm)	3.5-3.7	4.2	5.1	5.1-6.0
Antennule segments	4	4	4	4
Eye & stalk length (mm)	8.0-8.6	10.1	10.0	9.2-10.5
Maxilla 2	*	*	wide to mxp. 1	behind mxp. 1
Maxilliped 1	indicated	bud	*	with exopod
Maxilliped 2	*	*	exopod indicated	with exopod
Maxilliped 3	*	*	exopod indicated	with exopod
Coxal spines	*	*	*	*
Leg 1	*	*	*	*
Leg 2	*	*	*	*
Leg 3	*	*	*	*
Leg 4	*	*	*	*
Leg 5	2 segments	3 segments	4 segments	complete
Abdomen	*	pleopods bilobed	*	pleopods with protopod
Uropod	double, equal	*	*	*
Telson	*	*	*	*

* Same as previous stage.

General Description of Phyllosomes

The fore-body is pear-shaped throughout the larval development and is always slightly wider than the mid-body. In stage I, the eyes are not stalked but in stages II through XII they are borne on long slender stalks. Pigmented eye spots are found in every

stage. The statocysts are located in the fore-body just beneath the bases of the antenna and antennule. A brain, with nerve fibers running into the eye stalks and downward into the mid-body, is situated just under the apex of the eye stalks. The mandibles are large and well formed in stage I, and the larvae seems to be well adapted to feeding. Spots of red pigment are found around the mandibles and at the joints of the pereiopods of the early stages. The antenna are bilobed from stage I, where the lobes are almost equal; as the larvae increases in size the outer lobe becomes smaller than the inner lobe and in the later stages becomes flattened and more prominent. In the early stages both lobes of the antennae bear setae. The antennule begins as a single stalk, then obtains an endopod at stage V. Setae are found at the tip of the antennule during the early stages but are lost in later development. The first maxilliped is not obvious until about stage VIII when it is found in some larvae. Maxillipeds 2 and 3 are well developed in the first stage and undergo little change except for size until stage XI, when an exopod forms. The second maxilla in the early stages are composed of two segments, the distal one being a narrow bud terminating with four plumose setae. In the later stages the setae are lost and the distal segment increased in width extending behind the first maxilliped. Pereiopods 1 and 2 are well developed in stage I. Pereiopod 3 is also well developed but lacks setae on the short exopod. Pereiopods 4 and 5 appear as buds and then add segments one at a time as the larvae increases in size. All five pereiopods are complete at the time of metamorphoses into the puerulus. The uropods become evident in the sixth stage and are bilobed by stage IX. They reach full development by stage XI. Pleopods appear in stage IX as single lobes; in subsequent stages they become bilobed and are notched on the endopodite. In stage XII the pleopods are borne on a protopodite. Gills are found on the second and third maxilliped, pereiopods, 1-5, and on the dorsal mid-body at the insertion of the pereiopods, in stage XII only.

Stage XI is the same as Phyllosome C and stage XII is the same as Phyllosomes A and B, of my paper on four giant scyllarids (Sims, 1964).

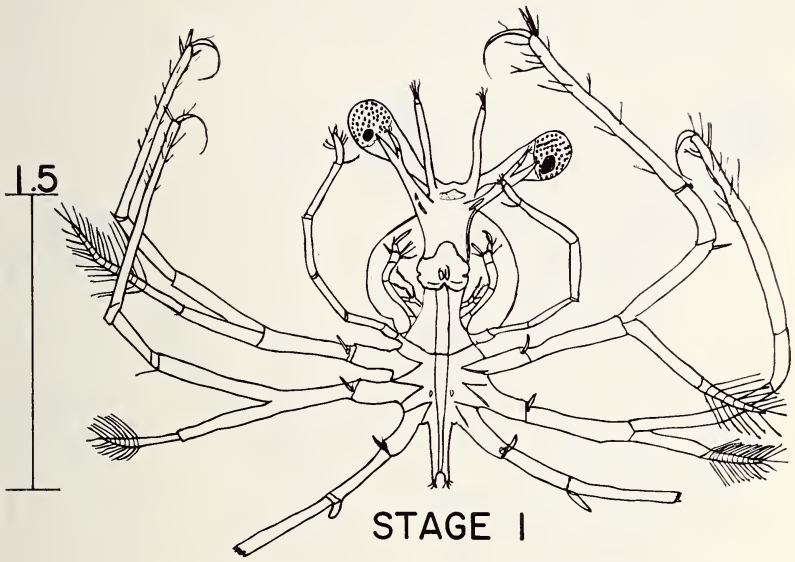

Fig. 1. Stage I of *Parribacus* sp. (ventral view).

Description of Phyllosomes by Stage

Stage I. Eye not stalked. Fore-body about as wide as long, but wider than mid-body. Eye slightly longer than antenna but almost equal to length of antennule. Antenna bilobed, lobes of equal size, inner lobe with 2 segments. Antennules unsegmented, with a single long setae about mid-way on the inner edge. Antenna and antennule without basal segment. Second maxilla elongated with two segments, the distal segment tipped with 4 plumose setae, first two longer than second two. Maxilliped 1 not present. Maxilliped 2 with 5 segments, the last with spines and a ring of setae, without exopod. Maxilliped 3 long and uniramous, without exopod or coxal spine. A bump on segment 2 of maxilliped 3 may be the presumptive exopod. Pereiopods 1 and 2 well developed, with coxal spine and accessory setae, with setose exopod, ending in a dactylus. Pereiopod 3 not as well developed, with short exopod not setose, with coxal spine and small accessory seta, ending in a subchela. Pereiopod 4 indicated, but not formed. Pereiopod 5 not present. Short setae are found along the edge and at the joints of all pereiopods. Abdomen narrow, sides almost

parallel, tip indented, tuffs of setae on each lobe. Telson and uropod not formed.

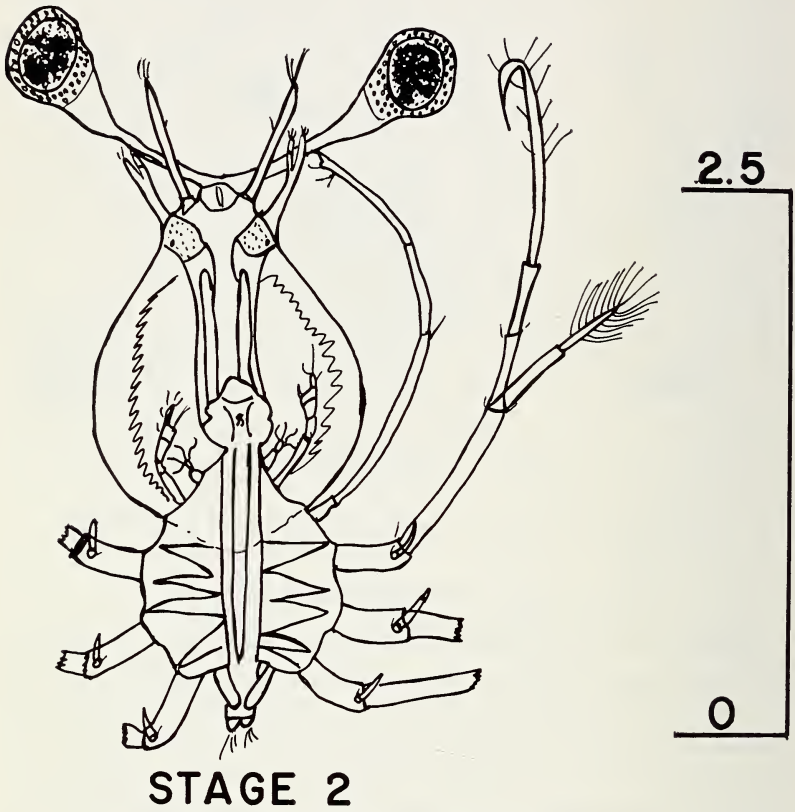

Fig. 2. Stage II of *Parribacus* sp. (ventral view).

Stage II. Eye stalked, eye and stalk slightly longer than antennule. Fore-body slightly longer than wide, wider than mid-body or hind-body. Antenna bilobed, inner lobe slightly shorter than outer lobe. Both lobes with terminal setae, inner lobe with 2 segments. Antennule with a single segment, inner edge setose. Antenna and antennule with basal segment. Second maxilla changed little from stage I. Maxilliped 1 not present. Maxillipeds 2 and 3 a little longer, without exopod or coxal spine. Pereiopods 1-3 with setose exopod, few setae on pereiopod 3 in some cases, all with coxal spine and small accessory seta, all ending in sub-

chela. Pereiopod 4 a bud formed close by the abdomen. Pereiopod 5 not present. Abdomen little changed over stage I. No telson or uropods.

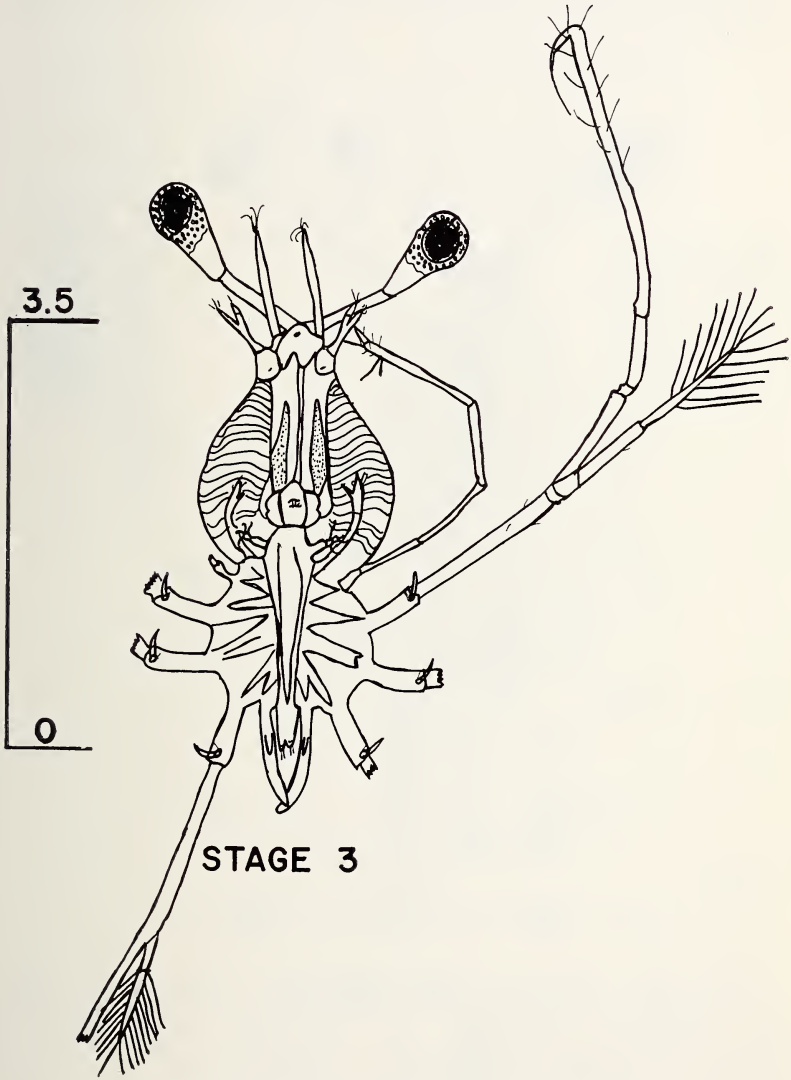

Fig. 3. Stage III of *Parribacus* sp. (ventral view).

Stage III. Fore-body longer than wide, slightly wider than mid-body. Pereiopod 4 a bud twice as long as abdomen, with short exopod in some cases, not bearing setae. Pereiopod 5 indicated but not formed. All other features show little change except in size.

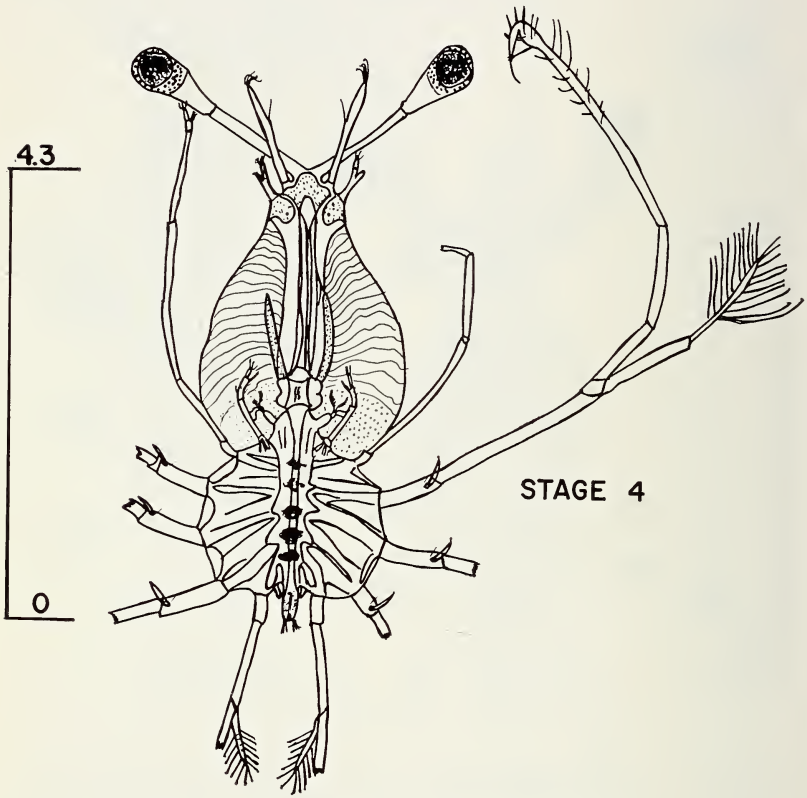

Fig. 4. Stage IV of *Parribacus* sp. (ventral view).

Stage IV. Fore-body longer than wide, only slightly wider than mid-body. Pereiopod 4 well developed, with exopod not bearing setae, without coxal spine. Pereiopod 5 a bud just free of abdomen. Antenna with outer lobe shorter than inner lobe, inner lobe with 2 segments. Antennule a single segment with indication of endopod forming. Abdomen small, rounding at the tip,

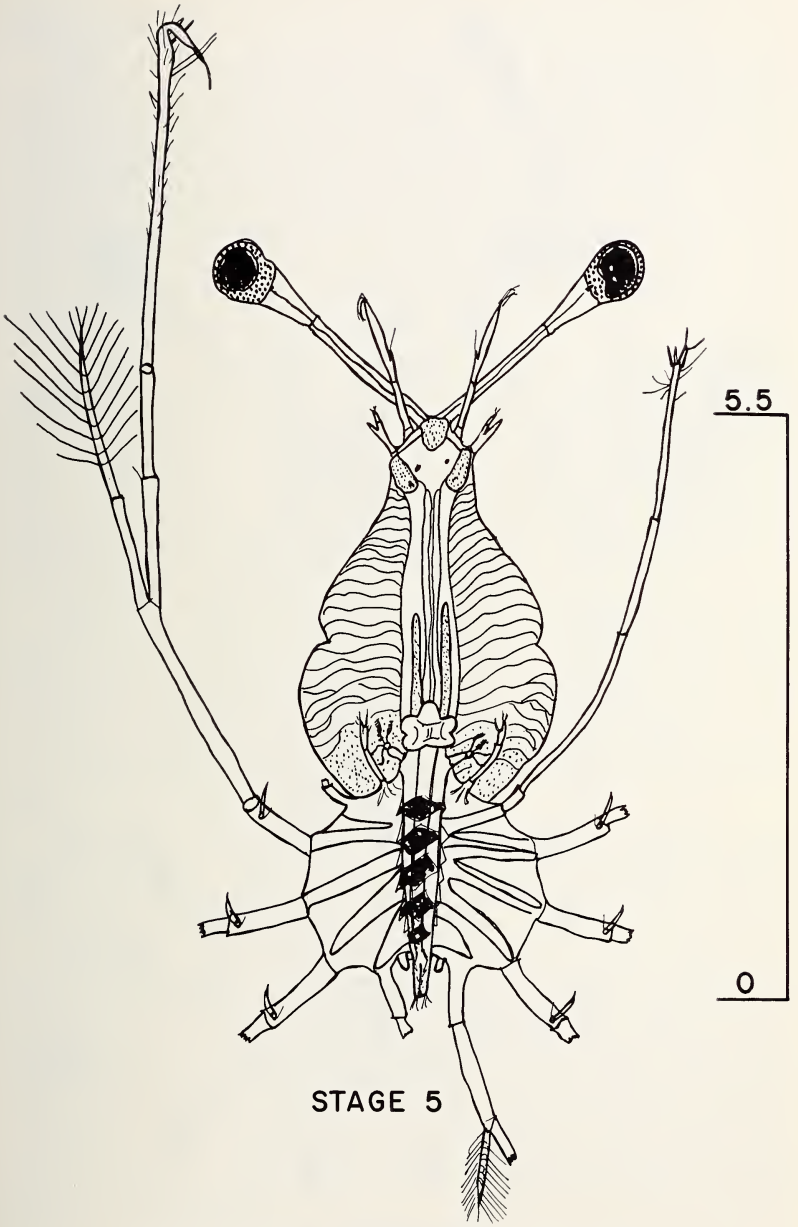

Fig. 5. Stage V of *Parribacus* sp. (ventral view).

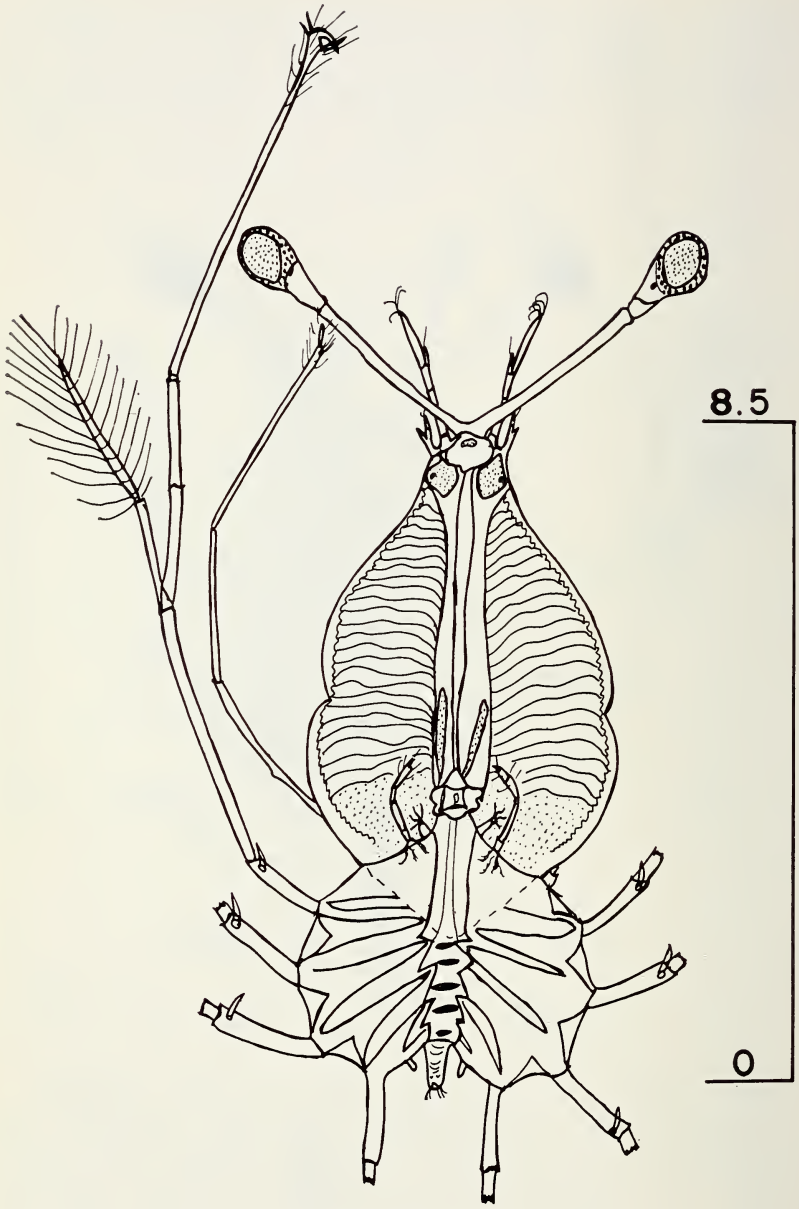

Fig. 6. Stage VI of *Parribacus* sp. (ventral view).

tip indented slightly, both lobes setose. All other features show little change.

Stage V. Fore-body longer than wide, wider than mid-body. Eye and stalk longer than antennule. Antennule with peduncle and two segments, with short endopod. Antenna, second maxilla and maxillipeds show little change over previous stages. Pereiopods 1-4 with setose exopods, 1-3 with coxal spine, all end in subchela. Subchela of pereiopod 3 the largest. Pereiopod 5 a bud, well away from abdomen. Segmentation indicated on the abdomen, abdomen slightly rounded at the tip, with tuffs of setae. Uropods indicated but not formed.

Stage VI. Fore-body wider than mid-body. Antennule with well-formed endopod, with peduncle and 3 segments. Antenna shows no change except in size. Second maxilla expanded at the base, segment 2 a small bud toward the lower edge, with four setae. Maxilliped 1 not apparent. Maxillipeds 2 and 3 and pereiopods 1-4 as before. Pereiopod 5 a bud, further from abdomen. Abdomen segmented, single uropod lobes formed. Telson indented slightly, lobes with few terminal setae.

Stage VII. Antennule as in stage VI. Antenna with 3 segments. Second maxilla expanded at base, a row of setae formed along upper edge, segment 2 very small and without setae. Maxilliped 1 not apparent. Maxillipeds 2 and 3 unchanged. Pereiopods 1-4 without coxal spine or accessory seta. Single uropods well developed. Telson only slightly indented, without terminal setae.

Stage VIII. Antennule with peduncle and 4 segments, last segment bilobed. Uropods formed as two, one smaller than the other. Indication of pleopods on abdomen. All other features unchanged except for size.

Stage IX. Antennule as in stage VIII. Antenna with 4 segments, second segment expanded and paddle-shaped. Maxilliped 1 formed as a bud. Maxillipeds 2 and 3 unchanged. Second maxilla well expanded at the base, segment 2 very small, setae along upper edge of segment one. Pereiopods 1-4 as before. Subchela of pereiopod 3 long and knife-like. Pereiopod 4 with 2 segments, without exopod. Two well developed uropods present, the inner lobe only slightly smaller than the outer. Telson round. Pleopods formed as single lobe.

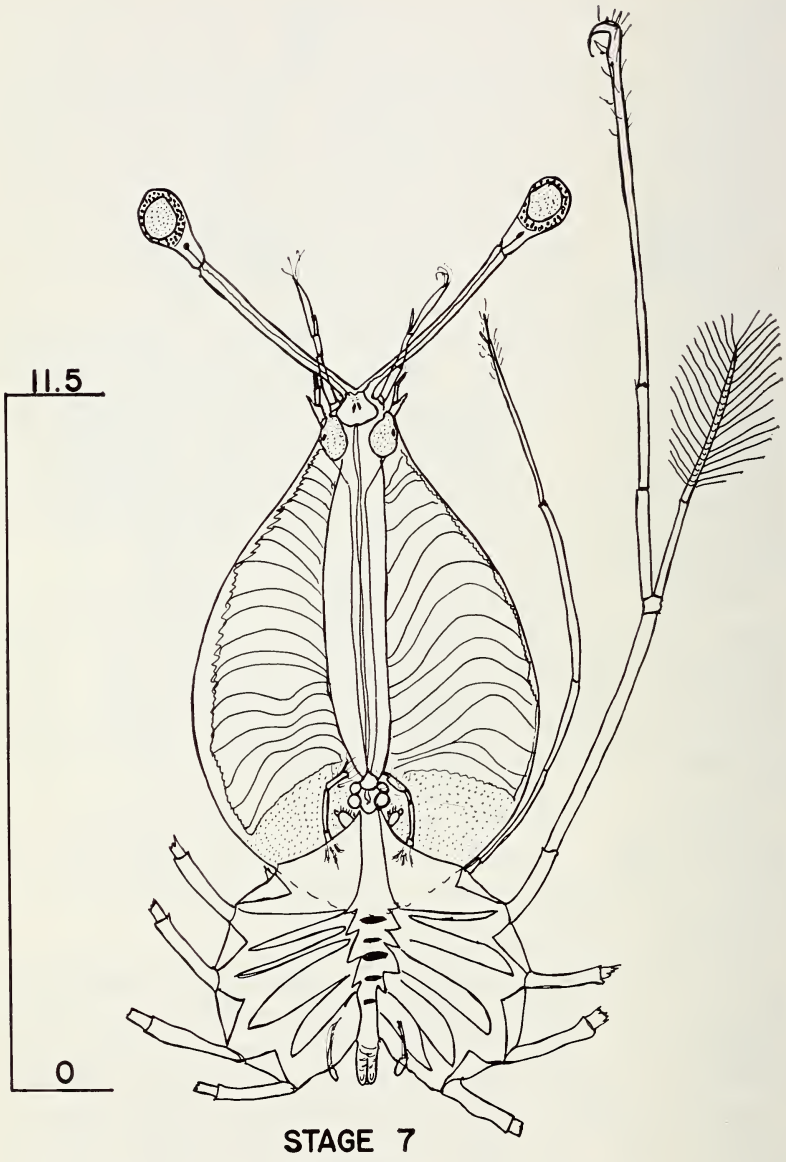

Fig. 7. Stage VII of *Parribacus* sp. (ventral view).

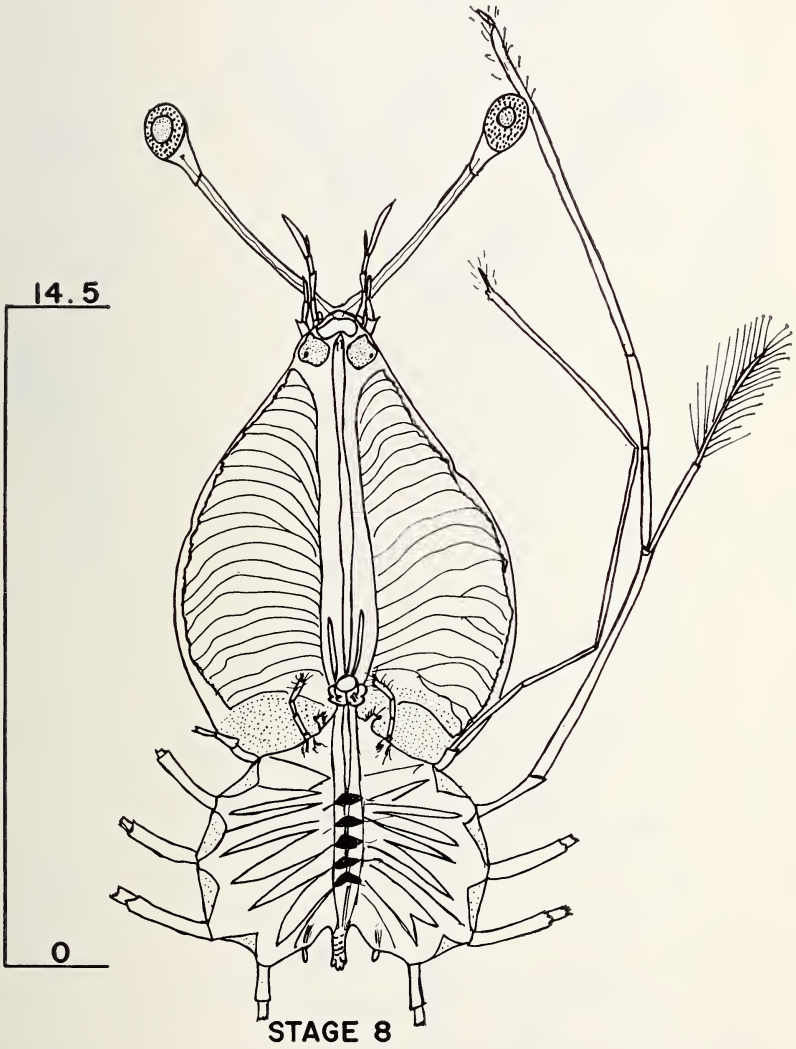

Fig. 8. Stage VIII of *Parribacus* sp. (ventral view).

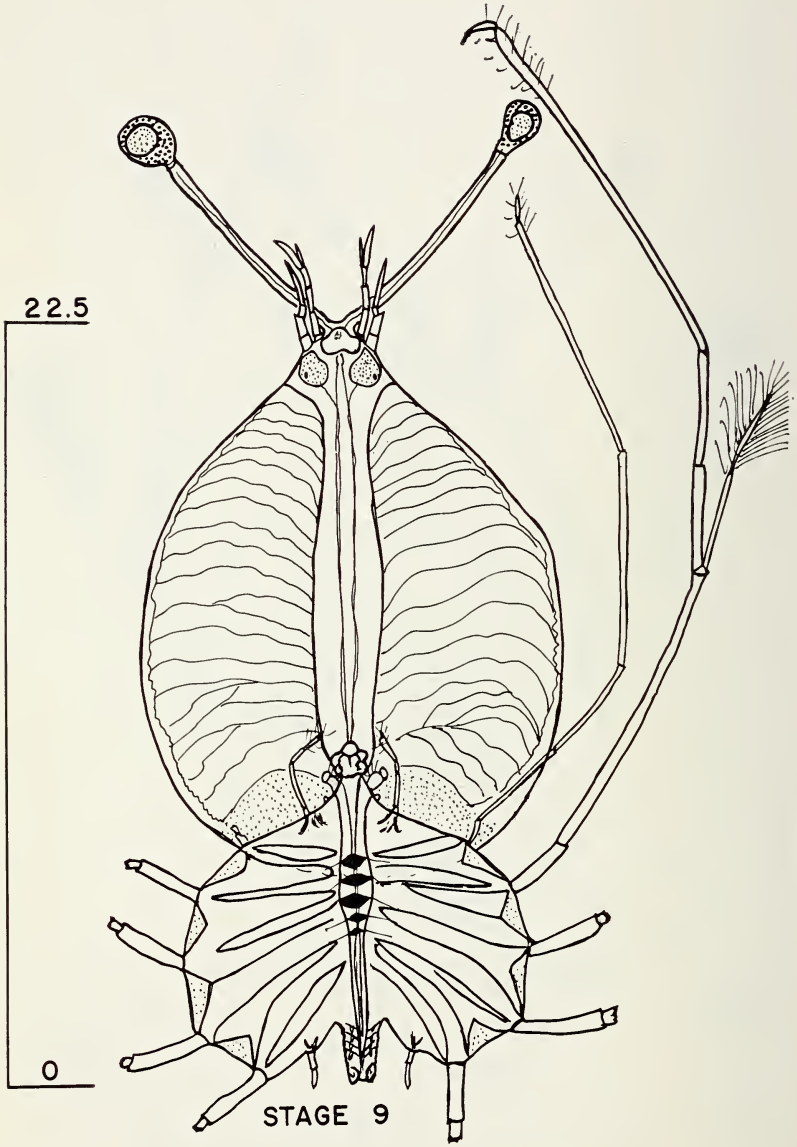

Fig. 9. Stage IX of *Parribacus* sp. (ventral view).

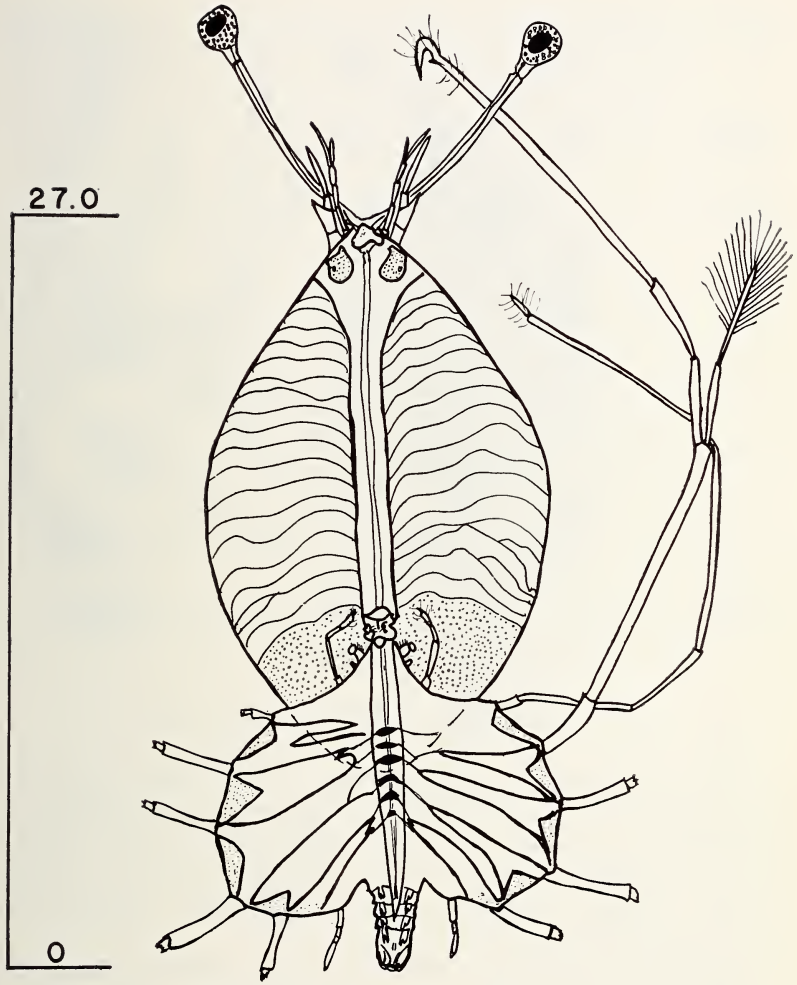

Fig. 10. Stage X of *Parribacus* sp. (ventral view).

Stage X. Antenna, antennula, second maxilla and maxillipeds unchanged except for size. Pereiopods 1-4 unchanged. Pereiopod 5 with 3 segments and shore exopod. Uropods almost equal in size. Telson well rounded. Pleopods lightly bilobed, without protopodite.

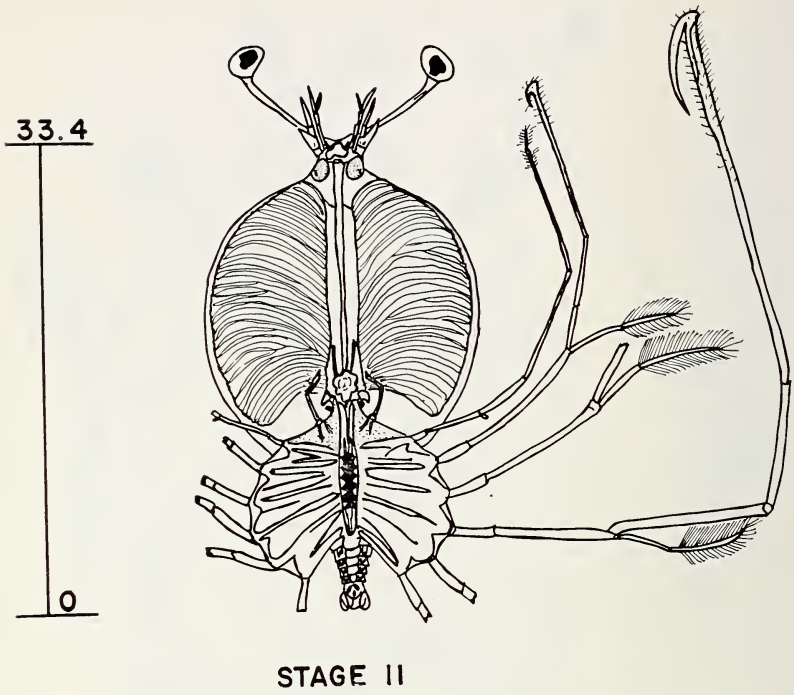

Fig. 11. Stage XI of *Parribacus* sp. (ventral view).

Stage XI. Antenna and antennule as before. Second maxilla with segment two expanded and extending toward maxilliped 1. Maxilliped 1 a bud without exopod. Maxilliped 2 and 3 with indication of exopod. Pereiopods 1-5, uropods and telson well developed. Pleopods bilobed, without protopodite. Abdomen tapered toward telson, concave behind.

Stage XII: Final Stage. Fore-body not as wide as long, but much wider than mid-body. Eye and stalk longer than antenna or antennule. Antenna with peduncle and 3 segments, the first segment above the peduncle expanded into the shape of a paddle. Antennule with peduncle and four segments. Second maxilla without setae, with exopod expanded and reaching behind maxilliped 1. Maxilliped 1-3 with finger-like exopods, none bearing setae. Maxillipeds 2 and 3 with gills. Pereiopods 1-5 all bearing long natatory setae. Bilobed gills on segment one of pereiopods 1-5. An additional set of 3 gills on dorsal mid-body at the origin of

pereiopods 1-4. Telson and uropods well developed. Pleopods bilobed with protopodites, with notch on endopodite lobe. Abdomen tapered toward telson, concave behind.

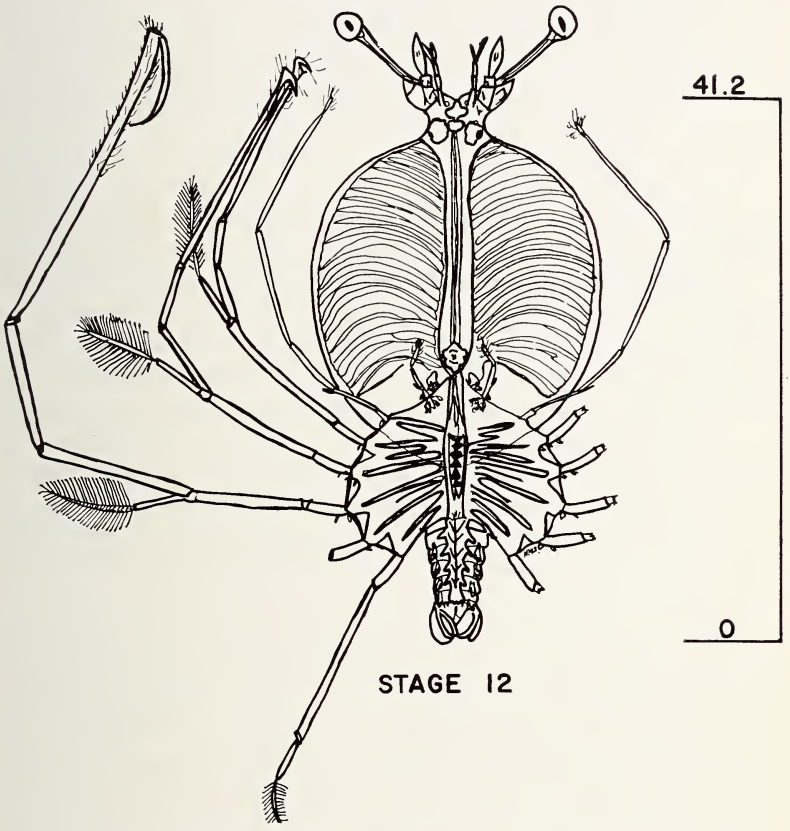

Fig. 12. Stage XII of *Parribacus* sp. (ventral view).

Discussion

Because of the bilobed antenna, which becomes large and paddle-shaped in later stages and the lack of the exopod on the third maxilliped in the early stages, it is apparent that these phyllosomes belong to the family Scyllaridae.

Saisho (1963) in his paper on the larvae of *Parribacus antarcticus* (Lund) suggested that there are two types of scyllarid phyllosomes, a Parribacus-type and an Ibacus-type. The Parribacus-type is

small when hatched, 1.05-1.6 mm, has only two of the five pereiopods fully developed, and the fore-body is only slightly wider than long. The Ibacus-type is much larger when hatched, an average of 3.0 mm., the fore-body is much wider than long, and pereiopods 1-3 are all fully developed. Pereiopod 4 is well developed but lacks setae on the exopod, and pereiopod 5 is without exception a bud. Saisho lists two genera in each type; in the Ibacus-type, *Thenus* and *Ibacus* and in the Parribacus-type, *Scyllarus* and *Parribacus.*

It is suggested by Gurney (1936) that phyllosomes similar to the ones illustrated in this report belong to the genus *Thenus.* Data now available show that Gurney's assumption was incorrect. Von Bonde (1932) and Holthuis (1946) report that there is a single species of the genus, *Thenus orientalis* (Lund) and that the adult population is restricted mainly to the Indopacific regions. It is possible that ocean currents could carry the phyllosomes into the Caribbean (Sims, 1964), but it is unlikely that the first stage would be found thousands of miles from the nearest adult populations. Holthuis (personal communication) stated that in the Indopacific, the adult lives on the muddy bottom and is collected in large numbers by shrimp trawlers. It would seem unlikely that a species with this type of habitat would be overlooked if it occurred in the Caribbean or Gulf of Mexico.

Prasad and Tampi (1957) successfully hatched the eggs of an ovigerous female of the species *Thenus orientalis.* In their paper they describe and illustrate the first stage phyllosoma larvae. Pereiopods 1-4 are well developed, the antenna is uniramous, and the fore-body is much wider than long. The average size is 2.95 mm. I feel that such data discount any theory that larvae described in this report could belong to the genus *Thenus.*

In his discussion of the phyllosome he provisionally called *Thenus* Gurney stated that he was uncertain that it belonged in the genus but because of the lack of knowledge of adult populations and their distributions he provisionally accepts the references of Stephensen (1923) and Santucci (1926) and doubtfully uses the designation *Thenus*? In his summary he suggested larvae so designated may rightfully belong to the genus *Parribacus,* but his treatment of this entire subject is difficult to interpret.

Saisho's Parribacus-type fits the description of stage I phyllosomes of this report and it is apparent that these belong to that

type. Many species of *Scyllarus* are reported in the Caribbean by Holthuis (1946). *Scyllarus americanus* Smith and *S. chacci* (Holthuis) are common in the Gulf of Mexico, but Chace (personal communication) feels that more species occur. As shown by Lebour (1950) the genus *Scyllarides* would fall into the Parribacus-type. Holthuis and Zaneveld (1958) and Boone (1930) report *Scyllarides americanus* Verrill and *Scyllarides acquinoctalis* (Lund) in the Caribbean area and Gulf of Mexico. *Parribacus* is reported mainly in the Indopacific region but is also reported by Holthuis (1946) in the Atlantic from the following areas: Caribbean Sea, Cuba, Santa Cruz, Virgin Islands, Barbados, Surinam, and Brazil. Holthuis and Zaneveld (1958) reported a single find of *P. antarcticus* on the beach of Klein Bonaire, in the Netherlands Antilles.

It is possible that two species of *Parribacus* occur: *Parribacus antarcticus* (Lund), widely distributed; and *Parribacus parrae* (H. Milne-Edwards), reported only in the West Indies. Holthuis (1946) feels that the two species are synonymous and that *P. parrae* is an aberrant form of *P. antarcticus.*

By comparison the phyllosomes of this report do not resemble the phyllosomes of *Scyllarus* spp. as discussed by Prasad and Tampi (1957, 1959, 1960) or Gurney (1936). Nor do they resemble the phyllosome of *Scyllarides* spp. shown by Lebour and Gurney. However, they compare closely with the phyllosome of *Parribacus antarcticus* hatched by Saisho. This comparison is parallel except for the presence of the first maxilliped and exopod on the third maxilliped found in Saisho's early stages. I find a bump on the second segment of maxilliped 3 but would not call this a true exopod. Later in the development the exopod forms from this, and for this reason I propose it be called a presumptive exopod rather than an exopod. Maxilliped 1 is not apparent on my larvae until they reach at least 11.0 mm. Again there is a spot I would rather call presumptive. If my larvae were in the genus *Parribacus,* these differences might mean I am working with another species.

A number of the early stages were sent to Dr. Saisho for comparison with his laboratory hatched individuals. Saisho (personal communication) states "The smallest phyllosomas are surely the first stage of *Parribacus* and the other advanced ones are, though there is no evidence, also of the same genus, I believe."

With this determination and the fact that the larvae seem to follow each other in stages, I feel that the larvae in this report be-

long to the genus *Parribacus*. There is not enough evidence at this time to put them into a species, and there is a need for more study on the adult populations that must occur throughout the areas in which my stage I was captured before a species determination can be made.

Distribution of Phyllosomes

During our regular sampling trips phyllosoma larvae were taken in the Yucatan Straits as far south as the Island of Cozumel; in the Gulf of Mexico north of the Yucatan Peninsula to the 100 fathom curve; throughout the Florida Straits and in the area of Dry Tortugas. Stage I of the species discussed in this report was taken in all areas.

Several specimens of this species were taken by incidental samples. The R/V *Oregon* collected several large, 8-15 mm phyllosomes in the northern Gulf of Mexico off the Texas and Louisiana coasts. Sixteen larvae were taken in the Florida Straits 14 miles south of Marathon, Florida. Several samples taken in the Gulf Stream east of St. Augustine, Florida, during the summer of 1962 produced many early stages including a single stage I. A few phyllosomes were collected by our shrimp biologists working in the Gulf of Mexico west of Florida to the 100 fathom curve.

Because our samples were taken in a random manner during this first year of study the data cannot be held statistically significant but do indicate some interesting information. Hatching must begin sometime between January and April and continue through August (see Table 1 and Fig. 13). First stage phyllosomes were taken in April, June, and August. In subsequent months only older stages were captured.

Saisho showed that the first stage of *Parribacus antarcticus* lasted only 9 or 10 days. Data collected in a drift-bottle study conducted in conjunction with this project indicate the most rapid transport by surface water from the Yucatan Straits to Florida is about 18 days. Other studies on the surface currents in this area (Guppy, 1937; Stewart, 1960; Salsman and Tolbert, 1963) report similar findings. This rate of flow is twice as long as the time needed for stage I to molt to stage II.

In June 1963 stage I phyllosomes were captured in the area just southwest of Dry Tortugas. From the data presented it is

doubtful these larvae were recruited from the Caribbean. An adult population must be present in the Gulf of Mexico.

In the Yucatan and Florida Straits stage I was taken in April and August, an indication that the spawning season must begin earlier and last longer in the Caribbean than in the Gulf of Mexico. Goodbody (1962) feels that spawing coincides with the periods of high phytoplankton production--the more tropical a zone, the longer this period. This could account for the longer spawning season in the Caribbean.

Figure 13 shows indication of a monthly progression in the mode and size range of the phyllosomes. This progression seems to begin in April, coinciding with the earliest capture of stage I, and then reaches a peak in December. Last stage phyllosomes were taken during December only, but large late stages were collected into January. In the following April no larvae larger than stage II were captured, an indication that all of last year's brood had reached maturity by this time. From these data it can be estimated that the length of larval life is about 9 months.

Effect of Ocean Currents on Distribution

Because of planktonic adaptation of the phyllosomes and the indicated larval life of 9 months, surface and sub-surface currents must play an important role in their transportation and distribution. The area of this study is under the direct influence of the

TABLE 5

Occurrence of phyllosomes in Area 1
(Yucatan Straits and northwestern Caribbean)

Date	Stations (no.)	Larvae (no.)	Length (mm)	Mean (mm)
Aug. 1962	7	4	4.0-5.9	4.7
Sept. 1962	1	2	3.3-7.2	5.2
Oct. 1962	3	0	—	—
Dec. 1962	1	0	—	—
Jan. 1963	0	—	—	—
April 1963	6	13	1.7-2.0	1.9
June 1963	10	14	1.8-18.1	5.3
Aug. 1963	0	—	—	—

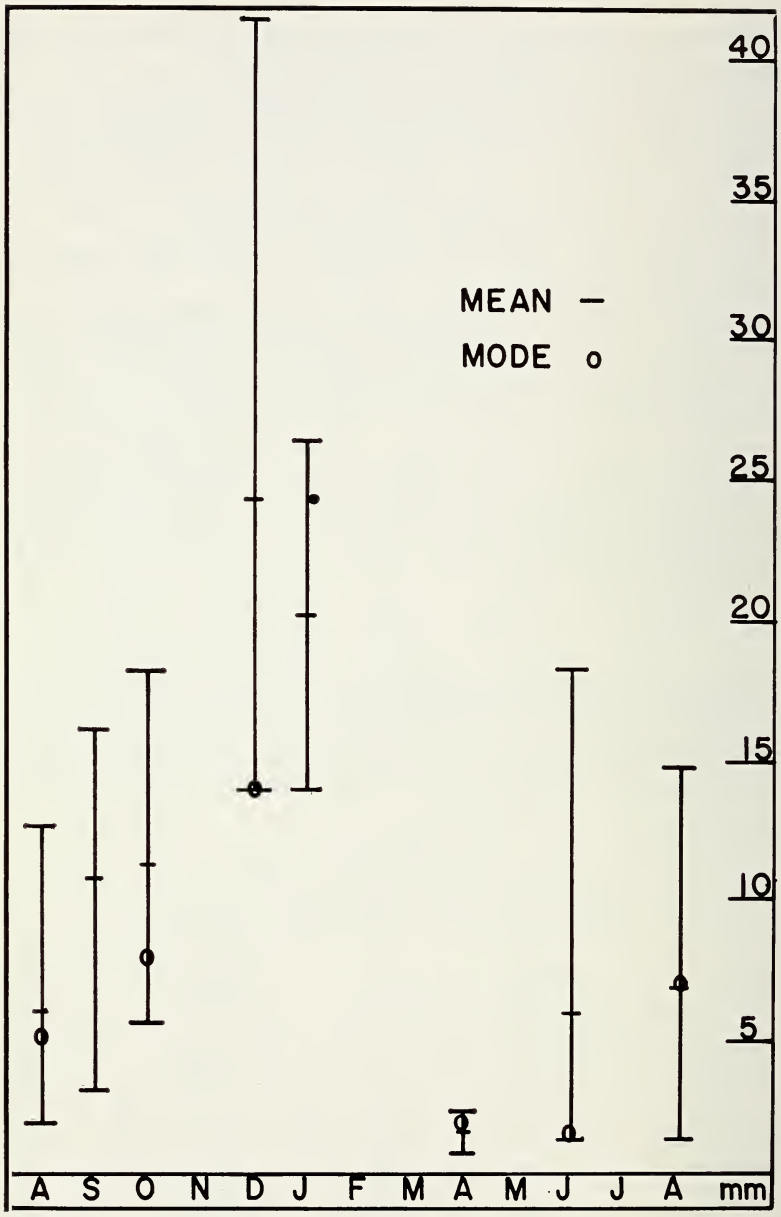

Fig. 13. Monthly size range in larvae of *Parribacus* sp.

Caribbean Sea, and a theory of the possible Caribbean origin of Florida's spiny lobster populations has been advocated by Ingle et al. (1963).

To illustrate the effect of currents on distribution I have divided the area sampled into 3 zones: Area 1 includes the Yucatan Straits and northwestern Caribbean; Area 2, the Florida Straits; and Area 3, Dry Tortugas and the Florida Keys. The data collected in these areas are shown on tables 5-7. Because of the small number of larvae captured during some trips, the mode serves of little value and is not recorded. Throughout the year the progression of values in areas 1 and 2 vary, while in area 3 they progress constantly toward larger values.

Walford (1938) implies that a variable progression indicates foreign recruitment, while constant progression in values indicates a stable population. Johnson (1960a,b), George and Cawthorn (1962), and Sheard (1949) show a constant progression in stages in the areas they sampled, a suggestion that the phyllosomes remain in local eddy systems and are able to re-enter coastal populations because of these eddies. In each case they state that many phyllosomes are no doubt lost from the eddy and that they are carried into foreign areas.

TABLE 6

Occurrence of phyllosomes in Area 2 (Florida Straits)

Date	Stations (no.)	Larvae (no.)	Length (mm)	Mean (mm)
Aug. 1962	13	60	2.1-10.1	4.6
Sept. 1962	14	2	15.6-16.0	15.7
Oct. 1962	20	19	5.6-15.0	9.4
Dec. 1962	17	6	19.5-41.2	25.5
Jan. 1963	9	0	—	—
April 1963	12	0	—	—
June 1963	24	19	3.3-11.7	7.4
Aug. 1963	11	6	1.7-1.8	4.0

Area 3 is situated in the lower sector of a large, rather stable cyclonic eddy (Salsman and Tolbert, 1963). Water enters this eddy from the northeastern Gulf. The eddy is generated by the so-called "Loop Current" which originates in the Yucatan Straits.

Because of the phyllosomes' short life in stage I, indicating they must hatch locally, and because of the constant progression in size that follows, it seems possible that these phyllosomes hatch in this area and that some of them remain in the eddy throughout the larval life. If this were not so the progression should vary as it does in areas 1 and 2.

TABLE 7

Occurrence of phyllosomes in Area 3
(Dry Tortugas and Florida Keys)

Date	Stations (no.)	Larvae (no.)	Length (mm)	Mean (mm)
Aug. 1962	2	33	3.0-12.0	9.0
Sept. 1962	6	1	12.0	12.0
Oct. 1962	4	18	9.5-18.0	13.5
Dec. 1962	9	8	14.0-29.2	19.5
Jan. 1963	4	3	14.0-26.2	21.2
April 1963	4	0	—	—
June 1963	25	12	1.6-10.5	2.7
Aug. 1963	16	1306	2.2-14.8	7.4

Although little is known about the local surface currents in the Caribbean Sea, studies by Guppy (1917), Sverdrup et al. (1949) and the Hydrographic Office (1952 and 1959) indicate that many cyclonic eddies exist. The final flow of Caribbean surface water is ultimately through the Yucatan Straits and into the Gulf of Mexico, Florida Straits, and Gulf Stream.

There are numerous reports of stable populations of adult lobsters throughout the Caribbean Sea. It is conjectural that such large populations are maintained entirely by foreign recruitment, and it is possibly true that local recruitment takes place because of the eddy systems. It is also assumed that many larvae are lost from the local eddies and enter into the flow through the Yucatan Straits. The mixing of the phyllosomes of many stages from many eddies is reflected in samples taken in the Yucatan and Florida Straits (Areas 1 and 2), where the bulk of this Caribbean loss is concentrated.

Some of the larvae are no doubt carried into the Gulf of Mexico and enter area 3, but because of possible cold water mortality in

the northern Gulf and a widespread distribution before entering the eddy, their effect on the local progression seems to be minor.

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Summary

During routine plankton sampling in the northwestern Caribbean Sea, the Gulf of Mexico, and the Atlantic Ocean east of Florida, a large number of phyllosoma larvae apparently belonging to the genus *Parribacus* were captured. Twelve of the many possible stages are illustrated and described. The finding of the first phyllosoma stage of this genus indicates that adult populations must occur in the Gulf of Mexico and Atlantic Ocean as well as the Caribbean Sea. Such populations have not been found or reported. The possible life history and distribution of the phyllosomes via ocean currents is given.

Literature Cited

Boone, P. L. 1930. Scientific results of the cruises of the yachts "Eagle" and "Ara", 1921-1928, William K. Vanderbilt commanding. Crustacea: Anomura, Macrura, Schizopoda, Isopoda, Amphipoda, Mysidacea, Cirripedia and Copepoda. Bull. Vanderbilt Oceanogr. Mus., vol. 3, pp. 1-221.

Bouvier, E. L. 1914. Recherches sur le développment post-embryonaire de la langouste commune (*Palinurus vulgaris*). Jour. Mar. Biol. Assoc., n.s., vol. 10, no. 2, pp. 179-193.

Costlow, J. D., Jr., and C. G. Bookhout. 1960. The complete larval development of *Sesarma cinereum* (Bosc) reared in the laboratory. Biol. Bull., no. 116, pp. 373-396.

George, R. W., and P. Cawthorn. 1963. Investigations on the phyllosoma larvae of the Western Australian crayfish. Report for 1962, Western Australian Mus., pp. 1-9 (mimeo.).

Goodbody, Ivan. 1962. Breeding seasons in tropical marine invertebrates. Asso. Island Marine Labs., 4th meeting.

Guppy, H. B. 1917. Plants, seeds, and the currents in the West Indies and Azores. Williams and Norgate, London, 531 pp.

Gurney, R. 1936. Larvae of decapod Crustacea. Part III. Phyllosoma. Discovery Rept., vol. 12, pp. 400-440.

Holthuis, L. B. 1946. The decapod Macrura of the Snellius Expedition. I. The Stenopodidae, Nephropsidae, and Palinuridae. Biol. Res. Snellius Expdn. XIV. Temminckia, vol. 7, pp. 1-178.

Holthuis, L. B., and J. S. Zaneveld. 1958. The scyllarid and palinurid lobsters of the Netherlands Antilles. Caraibisch Mar. Biol. Inst., no. 3, 26 pp.

Hydrographic Office. 1962. H. O. 128. Sailing directions for the West Indies. U. S. Government Printing Office.

———. 1959. H. O. 130. Sailing directions for the East Coast of Central America and Mexico. U. S. Government Printing Office.

Ingle, R. M., B. Eldred, H. W. Sims, and E. A. Eldred. 1963. On the possible Caribbean origin of Florida's spiny lobster populations. Florida Bd. Cons. Tech. Ser., no. 40.

Inoue, M., and M. Nonaka. 1963. Notes on the cultured larvae of the Japanese spiny lobster *Panulirus japonicus* (V. Siebold). Bull. Jap. Soc. Sci. Fish., vol. 29, no. 3, pp. 211-218.

Johnson, M. W. 1956. The larval development of the California spiny lobster *Panulirus interruptus* (Randall), with notes on *Panulirus gracilis* Streets. Proc. Calif. Acad. Sci., ser. 4, vol. 29, no. 1, pp. 1-19.

———. 1960a. The offshore drift of larvae of the California spiny lobster, *Panulirus interruptus*. Symposium on the changing Pacific Ocean in 1957 and 1958. Calif. Coop. Oceanic Fisheries Investigations Report, vol. 7, pp. 147-161.

———. 1960b. Production and distribution of larvae of the spiny lobster, *Panulirus interruptus* (Randall) with records on *P. gracilis* Streets. Bull. Scripps Inst. Oceanogr. U. of Calif., vol. 7, no. 6, pp. 413-462.

Lebour, M. V. 1950. Notes on some larval decapods (Crustacea) from Bermuda. Proc. Zool. Soc. London, vol. 120, no. 2, pp. 369-379.

Lewis, J. B. 1951. The phyllosoma larvae of the spiny lobster *Panulirus argus*. Bull. Mar. Sci. Gulf Carib., vol. 1, no. 2, pp. 89-103.

Nonaka, M., Y. Ohshima, and R. Hirano. 1958. Culture and ecdysis of spiny lobster at Phyllosoma stage. Aquiculture, vol. 5, no. 3, pp. 13-15.